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(54) **Optical modulation/multiplexing circuit**
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Description

[0001] The present invention relates to an optical modulation/multiplexing circuit, and more particularly to an optical modulation/multiplexing circuit of high-bit-rate optical pulses used for ultra-high-speed optical communications.

[0002] Fig. 4 is a block diagram showing a configuration of a conventional optical modulation/multiplexing circuit. The circuit comprises an optical modulation signal input port 401 (four channels in Fig. 4), an optical clock input port 402, a multiplexed optical signal output port 403, an optical filter 404, a planar lightwave circuit (PLC) substrate 405, a splitter 406, couplers 407, semiconductor optical amplifiers 408, a CW optical source 409, and a combiner 410.

[0003] First, optical modulation signals on a plurality of channels to be multiplexed are input through the optical modulation signal input port 401. Fig. 4 shows an example that inputs the four channel signals with the same bit rate. On the other hand, the optical clock signal with the same repetition rate as the bit rate of the modulation signal is input through the optical clock input port 402. The pulse width of the optical clock signal is narrower than the one time slot of the multiplexed signal.

[0004] The optical clock signal is split into optical clock signals of the same number of channels of the input optical modulation signals (four channels in this case) by the splitter 406. The optical clock signals propagate through optical waveguides formed on the PLC substrate, and are combined by the couplers 407 with the optical modulation signals propagating through optical waveguides on the PLC substrate. The optical clock signals and optical modulation signals, which are combined by the couplers 407, are input to the semiconductor optical amplifiers 408. In the semiconductor optical amplifiers 408, a four-wave mixing phenomenon, one of nonlinear optical effects, occurs by the incident optical clock signals and optical modulation signals. Thus, the semiconductor optical amplifiers 408 generate modulated optical pulses with a new wavelength and with optical intensities proportional to the optical intensity products between the optical clock signals and the optical modulation signals.

[0005] The wavelength λ_{FWM} of the newly generated four-wave mixing light is given by the following equation because of the energy conservation.

$$2/\lambda_{\text{FWM}} = 1/\lambda_{\text{sig}} + 1/\lambda_{\text{sig}} = 2/\lambda_{\text{sig}} = 1/\lambda_{\text{sig}} + 1/\lambda_{\text{clk}}$$

where λ_{sig} and λ_{clk} are wavelengths of the optical signals and optical clock signal, respectively.

[0006] The detail of relationship between each wavelength is closed by Govind P. Agrawal, "Nonlinear fiber optics (second edition)", Academic Press, 1995, ISBN0-12-045142-5, P.404, "Chapter 10, Parametric Process".

[0007] The CW optical source 409 launches bias light into the individual semiconductor optical amplifiers 408 in advance. This makes it possible to suppress the pattern effect in which the modulation efficiency varies depending on the signal pattern, thereby being able to stabilize their outputs.

[0008] The generated four-wave mixing light beams propagate through the optical waveguides along with the optical signals and optical clock signals, and are multiplexed by the combiner 410. In other words, the optical clock signal propagates through the waveguides on the PLC substrate from the splitter 406 whereby the optical signal is split to the couplers 407 whereby optical modulation signals are coupled. The generated four-wave mixing beams propagate through the waveguides on the PLC substrate until multiplexed with the optical modulation signals by the combiner 410. The lengths of the waveguides are designed such that the sum of the relative time difference between the channels through which the optical clock signals propagate and the relative time difference between the channels through which the four-wave mixing beams propagate becomes equal to one time slot of the multiplexed signal between adjacent channels. As a result, the optical modulation pulse outputs of the channels after the multiplexing are placed on the time axis at regular intervals.

[0009] Fig. 5 is a graph illustrating the output waveforms after the multiplexing on a time axis, that is, a horizontal axis. As referred to Fig. 5, the time-division-multiplexed output can be obtained by extracting only the four-wave mixing beams from the outputs of the PLC substrate by means of the optical filter 404.

[0010] However, the conventional integrated multiplexing circuit has the following problems. First, the conventional multiplexing circuit is comprised by the glass waveguides and the semiconductor optical amplifiers which are nonlinear optical devices on the same substrate. The two components, however, differ in diameters of the optical beams propagating through their waveguides. This causes a coupling loss of about 3 dB at each connection point, thereby degrading the signal-to-noise ratio. In addition, since the semiconductor optical amplifiers generate noise called amplified spontaneous emission noise, they also reduce the signal-to-noise ratio.

[0011] In addition, it is necessary for the conventional multiplexing circuit to launch the CW light beams to stabilize the generation of the four-wave mixing in the semiconductor optical amplifiers, which presents another problem of complicating the configuration. Furthermore, as clearly seen from the diagram showing the configuration, the optical

waveguides corresponding to the individual channels must be connected to the semiconductor optical amplifiers in implementing the circuit. This offers a problem of increasing time and effort for implementation in proportion to the number of channels.

[0012] The document "Optical network utilizing nonlinear optic devices -present and future-" by Kawanishi S., Lasers and Electro-Optics, 2001. CLEO/Pacific Rim 2001. The 4th Pacific Rim Conference on 15-19 July 2001, Piscataway, NJ, USA, IEEE, Vol. 1, 15 July 2001 (2001-07-15), Pages 1448-1449, discloses a recent progress in time domain optical signal processing based on optical nonlinear phenomena which is discussed to realize optical networks. All optical time-division multiplexing and add/drop multiplexing experiments are described as key functions of an optical network.

[0013] Further, document "Ultra-fast optical time division multiplexing" by Kawanishi S., Microwave Photonics, 2001. MWP '01. 2001 International Topical Meeting on Jan. 7-9, 2002, Piscataway, NJ, USA, IEEE, Vol. Supplement, 7 January 2002 (2002-01-07), Pages 25-28, discloses a recent progress in ultrahigh speed optical transmission using time-domain signal processing which is reviewed including optical short pulse generation, time-domain multiplexing/demultiplexing and timing extraction. A 120 Gbit/s system prototype is described.

[0014] The present invention is implemented to solve the foregoing problems. Therefore an object of the present invention is to fabricate a plurality of nonlinear optical waveguide devices and silica optical waveguides through a small number of process steps. Another object of the present invention is to achieve the simplification of the fabrication process by using the hybrid integration technique; and stabilization of the operation by reducing the connection, loss.

[0015] According to the present invention, this is accomplished by what is set forth in the appended independent claims. Advantageous modifications are defined in the appended dependent claims.

[0016] In summary, an all optical modulation and time-division-multiplexing circuit in accordance with the present invention employs as nonlinear optical switches, lithium niobate (LiNbO_3) optical waveguides with a domain inversion structure using cascaded $\chi^{(2)}$ processes. It implements the functions necessary for modulation and multiplexing such as input, splitting, multiplexing and timing adjustment of the optical signals and optical clock signal by connecting glass waveguides to the input and output terminals of the nonlinear optical waveguides.

[0017] According to the present invention, the PLC formed on the silicon substrate can be coupled to the plurality of domain inversion quasi-phase matching optical waveguides formed on the LiNbO_3 substrate at a time, thereby implementing the optical modulation and multiplexing circuit. Consequently, it can save time and effort for implementing it in spite of an increase in the number of the channels of the optical signals, and achieve low connection loss and low noise characteristic. Thus, the optical modulation/multiplexing circuit in accordance with the present invention offers great advantages when applied to high-speed optical communications.

[0018] The above and other objects, effects, features and advantages of the present invention will become more apparent from the following description of embodiments thereof taken in conjunction with the accompanying drawings.

Fig. 1 is a block diagram showing a configuration of an embodiment of the optical modulation/multiplexing circuit in accordance with the present invention;

Fig. 2A is a diagram showing an example of a domain inversion optical waveguide using quasi-phase matching;

Fig. 2B is a diagram showing an example of a domain inversion optical waveguide coupled the PLC substrate;

Fig. 3 is a graph illustrating the relationships between the wavelengths in two processes;

Fig. 4 is a diagram showing a configuration of a conventional optical modulation/multiplexing circuit; and

Fig. 5 is a graph illustrating behavior of output waveforms after multiplexing on a time axis which is a horizontal axis.

[0019] The invention will now be described with reference to the accompanying drawings.

[0020] Fig. 1 is a block diagram showing a configuration of an embodiment of the optical modulation/multiplexing circuit in accordance with the present invention. The present embodiment comprises an optical modulation signal input port 101, an optical clock input port 102, a PLC (planar lightwave circuit) substrate 103, a splitter 104, optical waveguides 105, couplers 106, a LiNbO_3 substrate 107, domain inversion optical waveguides 108, a PLC substrate 109, optical waveguides 110, a combiner 111, an optical filter 112 and a multiplexed optical signal output port 113.

[0021] The operation of the optical modulation/multiplexing circuit in accordance with the present invention will be described.

[0022] The present embodiment is the same as the conventional technique in that it modulates divided optical clocks with multiple optical modulation signals (eight-channel in Fig. 1), and multiplexes the modulated optical clocks on a time axis. The present embodiment, however, differs from the conventional technique in that it utilizes the characteristics of the nonlinear optical devices for carrying out all optical modulation. This enables the hybrid integration of the LiNbO_3 substrate with the PLC circuit and the multiplexing of the optical modulation signals much more efficiently than in the conventional technique. The present embodiment uses lithium niobate (LiNbO_3) optical waveguides with quasi-phase matching as the material of the domain inversion optical waveguides 108.

[0023] Fig. 2A is a diagram showing an example of the domain inversion optical waveguide using the quasi-phase matching. The domain inversion optical waveguide includes an optical waveguide 201. and domain inversion regions 202.

[0024] The device has a domain inversion polarization grating with a period Λ formed in the direction perpendicular to the traveling direction of the optical waveguide. The lithium niobate (LiNbO_3) optical waveguide with the quasi-phase matching utilizes a second order nonlinear optical phenomenon ($\chi^{(2)}$ process) as a nonlinear optical phenomenon. The present invention carries out wavelength conversion through a cascaded $\chi^{(2)}$ processes that cause two second order nonlinear optical effects simultaneously in the optical waveguide. First, the incoming optical modulation signal causes second harmonic generation (SHG) based on the first second order nonlinear optical effect, followed by generating a light beam with a wavelength half that of the optical modulation signal. Subsequently, the generated SHG light beam produces a difference frequency generation (DFG) phenomenon, based on a second second-order nonlinear optical effects, between the SHG light beam and the optical clock, thereby generating an output light beam with a new wavelength.

[0025] The wavelength λ_{out} of the output light beam generated in the cascaded process is given as follows.

$$\lambda_{\text{SHG}} = \lambda_{\text{sig}}/2 \quad (1)$$

$$1/\lambda_{\text{out}} = 1/\lambda_{\text{SHG}} - 1/\lambda_{\text{clk}} \quad (2)$$

[0026] Hence

$$1/\lambda_{\text{out}} - 1/\lambda_{\text{sig}} = 1/\lambda_{\text{sig}} - 1/\lambda_{\text{clk}} \quad (3)$$

where λ_{sig} is the wavelength of the optical modulation signal, λ_{SHG} is the wavelength of the SHG light beam and λ_{clk} is the wavelength of the optical clock signal. Fig. 3 shows the relationships between the wavelengths in the two processes. Fig. 3 illustrates that the difference between the optical frequency of the output light beam and that of the optical modulation signal is equal to the difference between the frequency of the optical modulation signal and that of the optical clock signal.

[0027] The relationship is the same as the third-order nonlinear optical phenomenon ($\chi^{(3)}$ process) such as phenomenon caused by the four-wave mixing. In the 1.55-micrometer wavelength band, the output light beam and the optical clock signal are nearly line symmetry with respect to the optical modulation signal in their wavelengths. The LiNbO_3 optical waveguide with the quasi-phase matching structure using the cascaded $\chi^{(2)}$ processes has a larger nonlinear optical constant than that using the $\chi^{(3)}$ process. In the foregoing reference, a four centimeter long device generates the output nearly equal to the output of the four-wave mixing of an optical fiber of about one kilometer. In the conventional configuration, the wavelength of the optical modulation signal is set at 1550 nm.

[0028] When a light beam with a different wavelength propagates through the LiNbO_3 optical waveguide, a phase mismatch occurs. The phase mismatch $\Delta\beta$ is given by the following equation.

$$\begin{aligned} \Delta\beta &= \beta_{\text{SHG}} \cdot \beta_{\text{sig}} - \beta_{\text{out}} \\ &= (n_{\text{SHG}}/\lambda_{\text{SHG}}) \cdot (n_{\text{sig}}/\lambda_{\text{sig}}) - (n_{\text{out}}/\lambda_{\text{out}}) \end{aligned} \quad (4)$$

[0029] The phase mismatch periodically makes the SHG conversion efficiency and DFG conversion efficiency in the LiNbO_3 optical waveguide zero at the phase 2π . Accordingly, extending the waveguide cannot increase the conversion efficiency. The domain inversion polarization grating structure compensates for the phase mismatch by inverting the polarization of the crystal in the regions at which the phase mismatch shifts from π to 2π , thereby securing a high conversion efficiency. The period Λ of the polarization inversion is determined such that the phase matching conditions for the propagation constants of the SHG light beam, incoming light beam and outgoing light beam in the optical waveguide satisfy the following equation.

$$\beta_{\text{SHG}} = \beta_{\text{sig}} + \beta_{\text{out}} + 2\pi/\Lambda \quad (5)$$

where Λ is about 14 micrometers when the wavelength of the optical modulation signal is 1550 nm.

[0030] Another characteristic of the optical waveguide in accordance with the present invention is that the mode field diameter of a light beam propagating through the optical waveguide is approximately equal to the diameter of a single mode optical fiber (about eight micrometers in diameter). Therefore the insertion loss (at 1550 nm wavelength band) is about 3 dB between single mode optical fibers which are attached to both ends of the 4-cm-long domain inversion optical waveguide. Considering that the propagation loss of the domain inversion optical waveguide itself is about 0.35 dB/cm, the connection loss between the single mode optical fiber and the present waveguide is about 1.3 dB, which is much smaller than the loss associated with the conventional semiconductor optical amplifier.

[0031] The technique for the low loss connection between the lithium niobate (LiNbO₃) optical waveguide itself and the single mode optical fiber with the quasi-phase matching the present embodiment employs is disclosed by S. Kawanishi, M.H. Chou, K. Fujiura, M.M. Fejer and T. Morioka, "All Optical Modulation and Time-Division-Multiplexing of 100 Gbit/s Signal using Quasi-Phasematched Mixing in LiNbO₃ Waveguides" Electron Lett., 36, 1568-1569 (2000).

[0032] Focusing attention to the characteristics the present waveguide has, in the present embodiment, the plurality of domain inversion optical waveguides formed on the LiNbO₃ substrate 107 are connected to the PLC substrate directly. Thus, it can implement all optical modulation/multiplexing with a stable and very simple configuration.

[0033] First, a plurality of optical modulation signals to be multiplexed are incident onto the optical modulation signal input port 101. Although Fig. 1 shows the case where eight channels of NRZ optical modulation signals are input, the number of channels can be set freely. In addition, the coding scheme of the optical modulation signal is not limited to NRZ. Any other coding schemes such as RZ are applicable as long as they are intensity modulation.

[0034] On the other hand, the optical clock signal is input to the optical clock input port 102, split by the splitter 104, and combined with the individual input optical modulation signals by the couplers 106. The lengths of the waveguides on the PLC substrate used for launching into the nonlinear optical devices and the lengths of the waveguides on the PLC substrate up to the multiplexing of the outputs of the nonlinear optical devices are designed in the same manner as those in the conventional technique. Consequently, the time-division-multiplexed light is output in which the input signals are arranged at regular intervals on a time axis.

[0035] In the present embodiment, the plurality of domain inversion optical waveguides 108, that is, the nonlinear optical devices on the LiNbO₃ substrate 107, are formed at regular intervals. The present embodiment is characterized in that the intervals are made equal to the intervals on the connecting portions of the optical waveguides 105 and 110 formed on the PLC substrate 103 and 109 to the LiNbO₃ substrate 107. These waveguides can be formed at a time using a photolithography technique, and setting the intervals of the waveguides in the connecting portions at the regular intervals enables hybrid integration in a single splicing process. As a result, the time and effort to carry out the splicing can be greatly reduced as compared with the conventional technique that connects the individual nonlinear optical devices to the optical waveguides one by one.

[0036] As a method for splicing the substrates at a time, each of which includes a plurality of waveguides arranged at the regular intervals, there is a following method. First, waveguides on both PLC substrates and domain inversion optical waveguides are placed closely. Second, a light signal is launched into an appropriate one (such as one at the edge) of the plurality of waveguides. Third, the position of the substrates is adjusted with monitoring the intensity of the output light. The coupling loss between the substrates becomes minimum at the position at which the intensity becomes maximum. Since the intervals of the waveguides are identical in the two substrates, all the waveguides are spliced optimally through the foregoing process.

[0037] In addition, the connection loss can also be reduced because the mode field diameter of the optical pulses propagating through the optical waveguides on the LiNbO₃ substrate is approximately equal to the mode field diameter of the PLC waveguides (about eight micrometers). To splice the PLC substrate to the LiNbO₃ substrate, the existing technique is applicable. As for the splicing of the two PLC substrates, it is disclosed by F. Ebisawa et al., "High-speed 32-channel optical wavelength selector using PLC hybrid integration", Technical Digest of Optical Fiber Communication conference (OFC), paper ThB1, San Diego, 1999. The technique is applicable to the splicing of the two different substrates, the PLC substrate and the LiNbO₃ substrate, enabling the implementation of the optical modulation and multiplexing circuit in accordance with the present invention.

[0038] Implementing the optical modulation/multiplexing circuit in accordance with the present invention in this way can not only reduce the size of the circuit and stabilize its operation, but also reduce the connection loss. Consequently, it can produce high signal-to-noise ratio output free from the noise of the semiconductor optical amplifiers, which cannot be avoided in the conventional technique.

[0039] The present invention has been described in detail with respect to preferred embodiments, and it will now be apparent from the foregoing to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspect, and it is the intention, therefore, in the apparent claims to cover all such changes and modifications as fall within the scope of the invention.

Claims

1. An optical modulation/multiplexing circuit comprising:

(N + 1) input ports (101) each for inputting one of an optical clock signal with a fixed repetition period t and N optical modulation signals with the period t, where N is an integer greater than one;
 splitting means (104) for splitting the optical clock signal into N portions;
 first combining means (106) for making each of N optical clock signals, split by said splitting means, delay with certain time differences, and for multiplexing each of the N optical modulation signals with one of the optical clock signals made delay with the time differences;
 N nonlinear optical waveguides (108) for generating an output light beam by second order nonlinear optical effect;
 second combining means (111) for receiving N output light beams generated by said N nonlinear optical waveguides (108) respectively and for multiplexing them after making them delay with certain time differences;
 and
 means (112) for optically extracting from the output of said second combining means (111), only signal pulses corresponding to a wavelength component newly produced in said nonlinear optical waveguide (108), wherein the output of said second combining means (111), includes the wavelength component newly produced in said nonlinear optical waveguide (108), and signal pulses arranged at a regular period t/N on a time axis without being overlapped,

characterized in that

said N nonlinear optical waveguides (108) comprise a domain inversion structure (202) formed in the same inversion polarization period on a single nonlinear optical media substrate (107) connected with said first combining means (106) and said second combining means (111) directly.

2. The optical modulation/multiplexing circuit as claimed in claim 1, wherein the second order nonlinear optical effect produced in said nonlinear optical waveguide (108) is a difference frequency generation process, and wherein an optical frequency w_3 of the signal pulses with the wavelength component newly generated in said nonlinear optical waveguide (108) satisfies one of relationships $w_3 = w_1 - w_2$ and $w_3 = w_2 - w_1$, wherein w_1 is an optical frequency of the optical clock signal, and w_2 is an optical frequency of the signal pulses.
3. The optical modulation/multiplexing circuit as claimed in claim 1, wherein the second order nonlinear optical effect produced in said nonlinear optical waveguide (108) is difference frequency generation following second harmonic generation, and wherein an optical frequency w_3 of the signal pulses with the wavelength component newly generated in said nonlinear optical waveguide (108) satisfies one of relationships $w_3 = 2w_1 - w_2$ and $w_3 = 2w_2 - w_1$, wherein w_1 is an optical frequency of the optical clock signal, and w_2 is an optical frequency of the signal pulses.
4. The optical modulation/multiplexing circuit as claimed in claim 2 or 3, wherein splitting means (104), said first combining means (106), and said second combining means (111) are each composed of N silica waveguides disposed on a silicon substrate (109).
5. The optical modulation/multiplexing circuit as claimed in claim 4, wherein said N nonlinear optical waveguides (108) are N lithium niobate (LiNbO_3) optical waveguides, and wherein said N optical waveguides are disposed at regular intervals equal to intervals at an output end of the silica waveguides of said first combining means (106) disposed on said silicon substrate (109), or to intervals at an input end of the silica waveguides of said second combining means (111) disposed on said silicon substrate (109).

Patentansprüche

1. Optische Modulations-/Multiplexschaltung mit:

(N + 1) Eingangsanschlüssen (101) jeweils zum Eingeben entweder eines optischen Taktsignals mit einer festen Wiederholrate t oder N optischen Modulationssignalen mit der Periode t, wobei N eine ganze Zahl größer eins bezeichnet;
 einer Teilungseinrichtung (104) zum Aufteilen des optischen Taktsignals in N Abschnitte;
 einer ersten Kombinationseinrichtung (106) zum Verzögern jedes der durch die Teilungseinrichtung geteilten N optischen Taktsignale um bestimmte Zeitdifferenzen und zum Multiplexen jedes der N optischen Modulationssignale mit einem der verzögerten optischen Taktsignale;

onssignale mit einem der mit den Zeitdifferenzen verzögerten optischen Taktsignalen;
 N nicht linearen optischen Wellenleitern (108) zum Erzeugen eines Ausgangslichtstrahls durch einen nicht
 linearen optischen Effekt der zweiten Ordnung;
 einer zweiten Kombinationseinrichtung (111) zum Empfangen von durch die N nicht linearen optischen Wel-
 lenleiter (108) jeweils erzeugten N Ausgangslichtstrahlen und zu deren Multiplexen nach Verzögerung mit
 bestimmten Zeitdifferenzen;
 einer Einrichtung (112) zum optischen Extrahieren von nur solchen Signalimpulsen aus der Ausgabe der zweiten
 Kombinationseinrichtung (111), die einer in dem nicht linearen optischen Wellenleiter (108) neu erzeugten
 Wellenlängenkomponente entsprechen, wobei
 die Ausgabe der zweiten Kombinationseinrichtung (111) die in dem nicht linearen optischen Wellenleiter (108)
 neu erzeugte Wellenlängenkomponente sowie mit einer regelmäßigen Periode t/N auf einer Zeitachse ohne
 Überlappung angeordnete Signalimpulse beinhaltet,

dadurch gekennzeichnet, dass

die N nicht linearen optischen Wellenleiter (108) eine Domäneninversionsstruktur (202) aufweisen, die mit derselben
 Inversionspolarisationsperiode auf einem einzelnen nicht linearen optischen Trägersubstrat (107) ausgebildet ist,
 das mit der ersten Kombinationseinrichtung (106) und der zweiten Kombinationseinrichtung (111) direkt verbunden
 ist.

2. Optische Modulations-/Multiplexschaltung nach Anspruch 1, wobei der in dem nicht linearen optischen Wellenleiter
 (108) erzeugte nicht lineare optische Effekt der zweiten Ordnung ein Differenzfrequenzerzeugungsvorgang ist, und
 wobei eine optische Frequenz w_3 der Signalimpulse mit der in dem nicht linearen optischen Wellenleiter (108) neu
 erzeugten Wellenlängenkomponente eine der Beziehungen $w_3 = w_1 - w_2$ und $w_3 = w_2 - w_1$ erfüllt, wobei w_1 eine
 optische Frequenz des optischen Taktsignals und w_2 eine optische Frequenz der Signalimpulse bezeichnet.

3. Optische Modulations-/Multiplexschaltung nach Anspruch 1, wobei der in dem nicht linearen optischen Wellenleiter
 (108) erzeugte nicht lineare optische Effekt der zweiten Ordnung eine der Erzeugung einer zweiten harmonischen
 Schwingung folgende Differenzfrequenzerzeugung ist, und wobei eine optische Frequenz w_3 der Signalimpulse mit
 der in dem nicht linearen optischen Wellenleiter (108) neu erzeugten Wellenlängenkomponente eine der Beziehun-
 gen $w_3 = 2w_1 - w_2$ und $w_3 = 2w_2 - w_1$ erfüllt, wobei w_1 eine optische Frequenz des optischen Taktsignals und w_2
 eine optische Frequenz der Signalimpulse bezeichnet.

4. Optische Modulations-/Multiplexschaltung nach Anspruch 2 oder 3, wobei die Teilungseinrichtung (104), die erste
 Kombinationseinrichtung (106) und die zweite Kombinationseinrichtung (111) jeweils aus auf einem Siliziumsubstrat
 (109) angeordneten N Siliziumdioxidwellenleitern zusammengesetzt sind.

5. Optische Modulations-/Multiplexschaltung nach Anspruch 4, wobei die N nicht linearen optischen Wellenleiter (108)
 N optische Wellenleiter aus Lithiumniobat (LiNbO_3) sind, und wobei die N optischen Wellenleiter mit regelmäßigen
 Intervallen gleich den Intervallen an einem Ausgangsende der auf dem Siliziumsubstrat (108) angeordneten Silizi-
 umdioxidwellenleiter der ersten Kombinationseinrichtung (108) oder gleich den Intervallen an einem Eingangsende
 der auf dem Siliziumsubstrat (109) angeordneten Siliziumdioxidwellenleiter der zweiten Kombinationseinrichtung
 (111) angeordnet sind.

Revendications

1. Circuit de modulation/multiplexage optique comprenant :

(N + 1) ports d'entrée (101) chacun pour entrer l'un d'un signal d'horloge optique avec une période de répétition
 fixe t et de N signaux de modulation optiques avec la période t , où N est un entier supérieur à un ;
 un moyen de fractionnement (104) pour fractionner le signal d'horloge optique en N portions ;
 un premier moyen de combinaison (106) pour faire retarder chacun des N signaux d'horloge optiques, fractionnés
 par ledit moyen de fractionnement, de certaines différences temporelles, et pour multiplexer chacun des N
 signaux de modulation optiques avec un des signaux d'horloge optiques fait retarder des différences
 temporelles ;
 N guides d'onde optiques non linéaires (108) pour générer un faisceau lumineux de sortie par effet optique non
 linéaire de deuxième ordre ;
 un deuxième moyen de combinaison (111) pour recevoir N faisceaux lumineux de sortie générés par lesdits N

guides d'onde optiques non linéaires (108) respectivement et pour les multiplexer après les avoir fait retarder de certaines différences temporelles ; et

un moyen (112) pour extraire optiquement de la sortie dudit deuxième moyen de combinaison (111), uniquement les impulsions de signaux correspondant à une composante de longueur d'onde nouvellement produite dans

ledit guide d'onde optique non linéaire (108), dans lequel

la sortie dudit deuxième moyen de combinaison (111), inclut la composante de longueur d'onde nouvellement produite dans ledit guide d'onde optique non linéaire (108), et les impulsions de signaux agencées selon une période régulière t/N sur un axe temporel sans chevauchement,

caractérisé en ce que

lesdits N guides d'onde optiques non linéaires (108) comprennent une structure à inversion de domaine (202) formée dans la même période de polarisation d'inversion sur un substrat de milieu optique non linéaire unique (107) connecté avec ledit premier moyen de combinaison (106) et ledit deuxième moyen de combinaison (111) directement.

2. Circuit de modulation/multiplexage optique selon la revendication 1, dans lequel l'effet optique non linéaire de deuxième ordre produit dans ledit guide d'onde optique non linéaire (108) est un processus de génération de fréquence différentielle, et dans lequel une fréquence optique w_3 des impulsions de signaux avec la composante de longueur d'onde nouvellement générée dans ledit guide d'onde optique non linéaire (108) satisfait à l'une des relations $w_3 = w_1 - w_2$ et $w_3 = w_2 - w_1$, où w_1 est une fréquence optique du signal d'horloge optique, et w_2 est une fréquence optique des impulsions de signaux.

3. Circuit de modulation/multiplexage optique selon la revendication 1, dans lequel l'effet optique non linéaire de deuxième ordre produit dans ledit guide d'onde optique non linéaire (108) est une génération de fréquence différentielle faisant suite à une génération de deuxième harmonique, et dans lequel une fréquence optique w_3 des impulsions de signaux avec la composante de longueur d'onde nouvellement générée dans ledit guide d'onde optique non linéaire (108) satisfait à l'une des relations $w_3 = 2w_1 - w_2$ et $w_3 = 2w_2 - w_1$, où w_1 est une fréquence optique du signal d'horloge optique, et w_2 est une fréquence optique des impulsions de signaux.

4. Circuit de modulation/multiplexage optique selon la revendication 2 ou 3, dans lequel le moyen de fractionnement (104), ledit premier moyen de combinaison (106), et ledit deuxième moyen de combinaison (111) sont chacun composés de N guides d'onde de silice disposés sur un substrat de silicium (109).

5. Circuit de modulation/multiplexage optique selon la revendication 4, dans lequel lesdits N guides d'onde optiques non linéaires (108) sont N guides d'onde optiques au niobate de lithium (LiNbO_3), et dans lequel lesdits N guides d'onde optiques sont disposés à intervalles réguliers égaux aux intervalles à une extrémité de sortie des guides d'onde de silice dudit premier moyen de combinaison (106) disposés sur ledit substrat de silicium (109), ou aux intervalles à une extrémité d'entrée des guides d'onde de silice dudit deuxième moyen de combinaison (111) disposés sur ledit substrat de silicium (109).

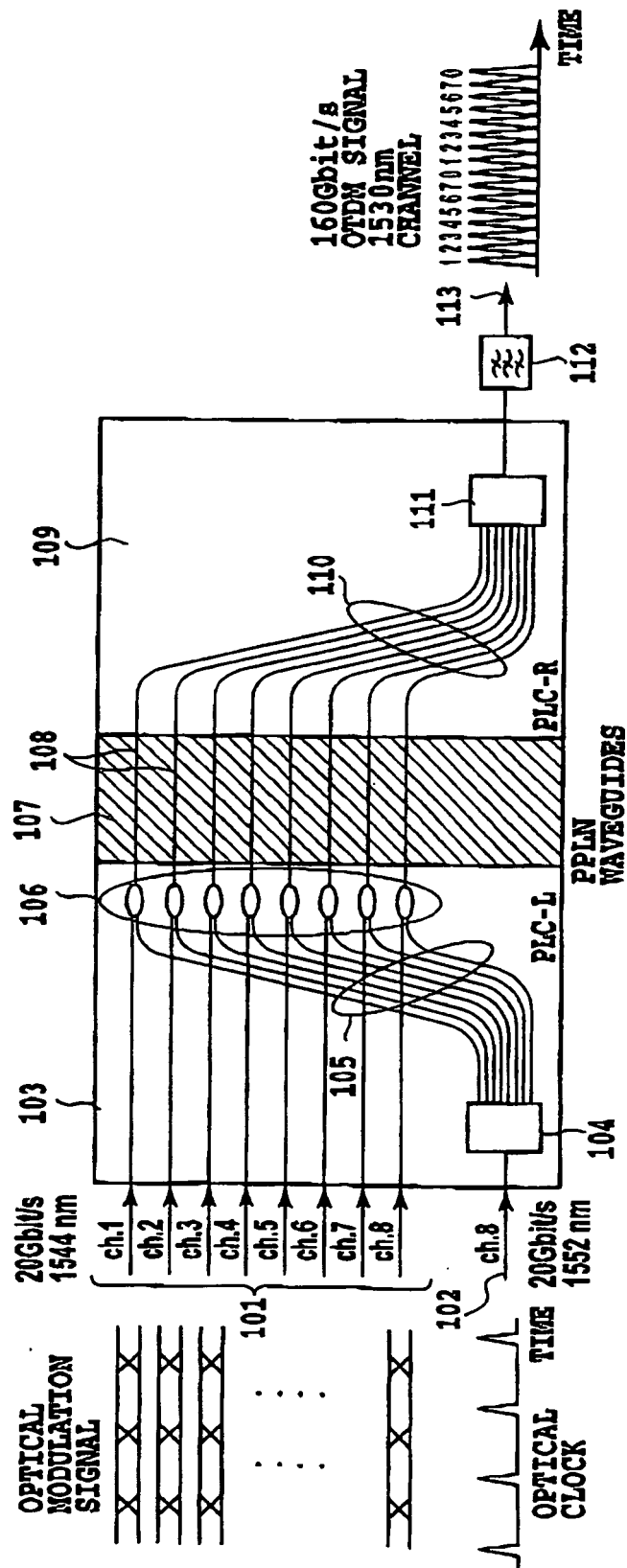


FIG.1

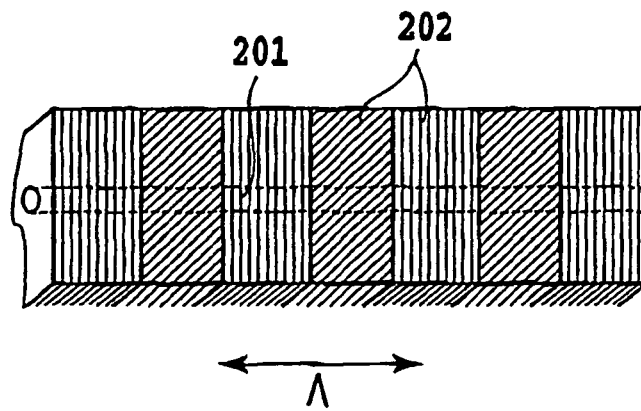


FIG.2A

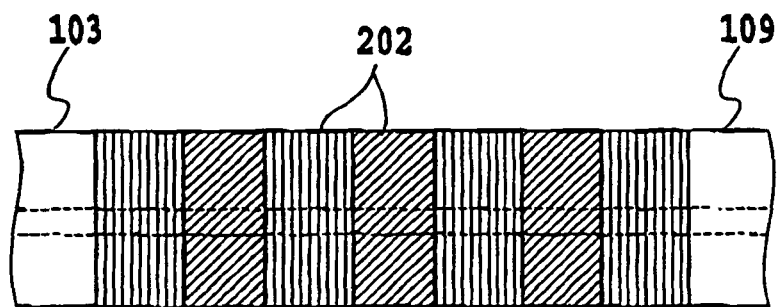
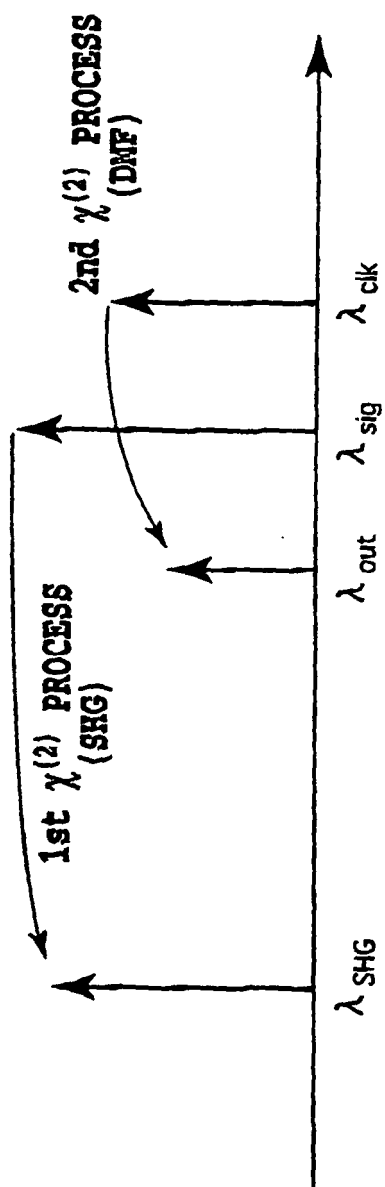


FIG.2B

**FIG.3**

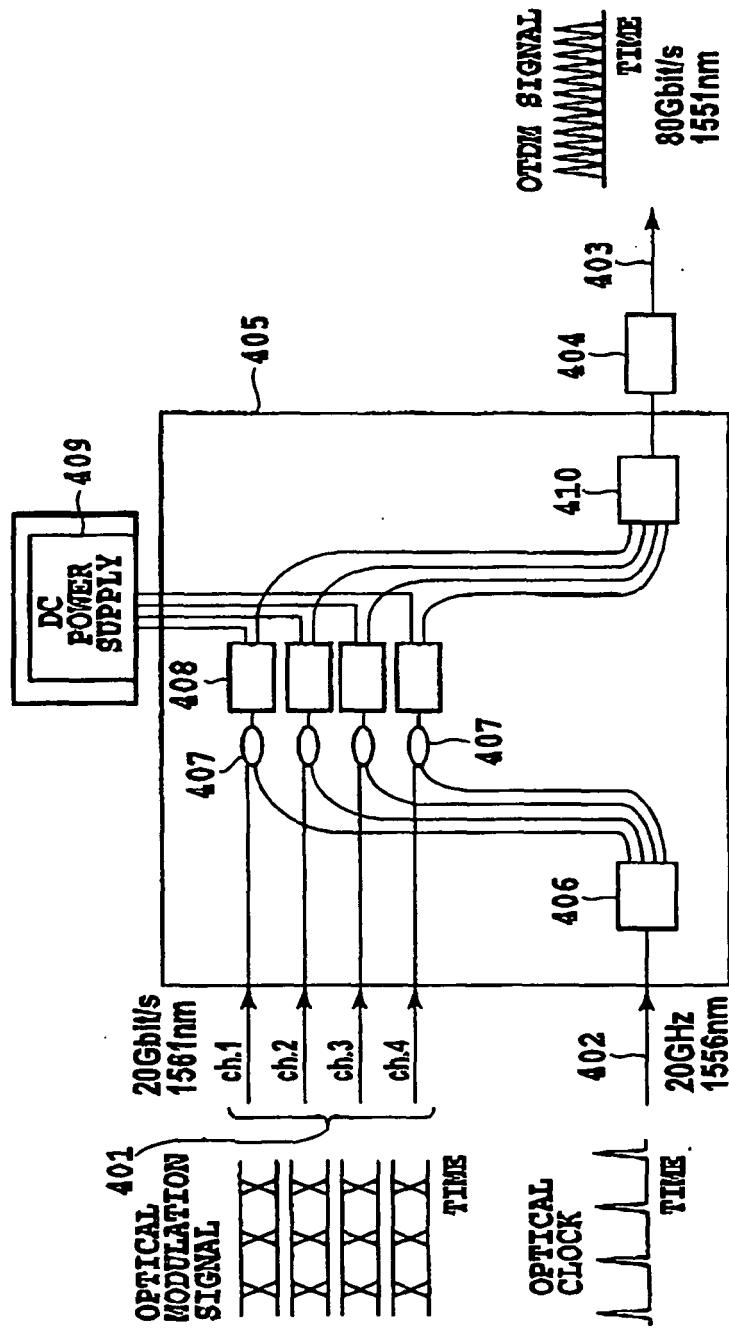


FIG.4

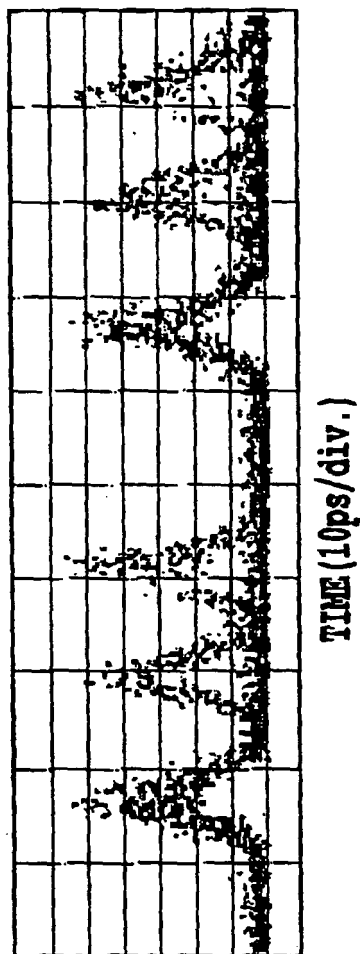


FIG.5

REFERENCES CITED IN THE DESCRIPTION

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